Rec. West. Aust. Mus. 1988, 14(1): 21-34

Observations on the environment and biology of *Schizomus vinei* (Chelicerata: Schizomida) from Cape Range, Western Australia

B. Vine*, B. Knott† and W.F. Humphreys‡

Abstract

The chelicerata order Schizomida is known in Western Australia by a single species, *Schizomus vinei* Harvey 1988, from only two caves (Dry Swallet and Shot Pot) in the semiarid Cape Range on the North West Cape peninsula. About 60 of the 120 caves known in Cape Range have been examined for fauna but most are too dry to support cavernicoles. The number of *S. vinei* seen in caves was low and the population comprised predominantly immature individuals. They were confined to areas where the relative humidity exceeded 90%. Following exceptionally heavy rainfall the chambers flooded to a depth of 27 m after which no adult schizomids were seen for three weeks or juveniles for three months. The environment and microclimate of the area are described, together with observations on the biology of the schizomids and their associated fauna.

Introduction

The arachnid order Schizomida has considerable intrinsic and zoogeographic significance but little is known of the general biology and ecology of schizomids. They are considered to have evolved from the ancestral stock which gave rise to spiders (Araneae) by the Devonian, and to whip scorpions (Uropygi) and tailless whip scorpions (Amblypygi) by the Carboniferous (Savory 1977), although their meagre fossil record commences only in the late Tertiary (?Pliocene; Petrunkevitch 1955). Schizomids are remarkably conservative, showing little morphological variation even between continents (Lawrence 1969). Only five recent genera are recognised within two families: the genus *Schizomus* contains more than 70 species while the remaining four genera contain only seven species (Levi 1982). Systematic knowledge of the order in the Ethiopian (Lawrence 1969) and the Nearctic and Neotropical (references in Rowland and Reddell 1981) zoogeographic regions has advanced recently but only one species of Australian schizomid has been described (Harvey 1988).

---

* 86 Schruth Street, Kelmscott, Western Australia 6111.

† Department of Zoology, University of Western Australia, Nedlands, Western Australia 6009.

‡ Department of Biogeography and Ecology, Western Australian Museum, Francis Street, Perth, Western Australia 6000.

Correspondence should be directed to Dr B. Knott.

Schizomids are widespread in Africa, India, south-east Asia through to northern Australia, some Indian Ocean and Pacific Islands and the lower latitudes of both American continents (Rowland 1975). They are constrained (by virtue of their small size and weakly sclerotised integument incapable of resisting desiccation) generally to moist microhabitats such as leaf litter, tunnels in soil, beneath rocks and to caves (Levi 1982), although schizomids have been collected while sweep netting brush (Rowland 1975). Hence the occurrence of schizomids in two caves (Dry Swallet, C 18 and Shot Pot, C 106) in the semiarid Cape Range on the North West Cape Peninsula (Main 1980; Harvey 1988), is of considerable zoogeographic interest; the area is separated by at least 1000 km of mainly arid country, including the Great Sandy Desert, from the nearest rainforest vegetation — vine thickets in the Kimberley Region of Western Australia. The closest known location of schizomids is near Darwin, Northern Territory (Cockendolpher 1981).

This paper presents observations on the distribution, habitat and biology of *Schizomus vinei* Harvey in Cape Range and considers the vulnerability of the populations to disturbance.

Description of the Cape Range area

Climate

The climate of the North West Cape peninsula is hot (mean daily temperature *ca* 27° C) and dry, with the annual evapotranspiration being 11 fold greater than precipitation (Table 1). Although the meteorological stations around Cape Range record some variation in mean monthly rainfall, probably reflecting local orographic influence, we consider there would be only minor differences between these stations and the localities of caves C 18 and C 106 on the crest of the range. Rainfall is low (Table 1) and, as it results from at least four processes (Gentilli 1972; Beard 1975), is highly variable (variability index 1.5-1.75)with heavy rain (> 100 mm) experienced on 11 occasions in 1957-1969 and 1976-1986 inclusive, twice in each of 1958, 1961, 1963 and 1964. This irregular heavy rainfall, which floods the caves, results from tropical cyclone (summer) and jet stream activities (late summer and autumn) (Gentilli 1971, 1979; Lourensz 1981). Of particular significance to cryptozoic animals unable to resist desiccation is the low relative humidity throughout the year and the low rainfall relative to evaporation (Table 1).

Vegetation

Cape Range lies in the Ashburton district of the Eremaean floristic province, a zone of desert adapted plants (Burbidge 1960). Cape Range is covered by tree steppe of *Eucalyptus dichromophloia* (to 6 m; *E. microtheca* in valleys) over spinifex (*Triodia* spp.), with shrubs (*Grevillea* sp., to 3 m and *Acacia* spp., to 2 m). Clumps of *Ficus platypoda* are found, often about the entrances of sink holes (Beard 1975).

Table 1 Climatic data for stations around the Cape Range, Western Australia, showing the extreme aridity of the surface environment. Evaporation (mm) and temperature (°C) data are from Learmonth (1975-1986). Rainfall (mm) is much more variable than temperature and the data presented are the mean values for a number of meteorological stations arund the Cape Range peninsula, namely Learmonth, Ningaloo, Vlaming Head, Yardie Creek, Exmouth Gulf and Exmouth.

	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Sum
Rainfall	26.5	37.3	48.2	18.9	57.1	51.1	22.3	14.5	2.0	3.2	1.8	1.5	284.4
Evaporation[1]	12.9	11.7	10.4	8.0	5.5	4.0	4.4	5.6	8.2	10.4	11.7	13.2	3219
Mean max. °C	37.6	38.3	36.4	32.5	28.3	24.8	24.2	25.8	29.1	31.3	34.0	37.5	31.7
Mean min. °C	23.1	24.4	23.5	20.1	15.9	12.8	11.4	12.8	13.8	15.7	18.4	21.2	17.8
0900 °C	29.3	29.9	28.9	25.6	21.8	18.5	17.5	19.0	21.1	23.8	26.1	29.0	24.2
1500 °C	35.6	36.3	35.2	31.4	27.3	23.9	23.2	24.7	28.0	29.8	32.4	35.7	30.3
0900 R.H.	51	52	55	58	58	66	64	59	47	42	44	42	53
1500 R.H.	33	34	33	36	37	43	38	37	25	25	27	26	33

[1] Evaporation is expressed as the mean daily rate except for the sum which is the annual rate.

Sources of rainfall and evaporation data: for Exmouth, Learmonth and Yardie Creek:— Microfiche Climatic Averages, Austalia 1957-1969 and all available information over the years 1915-1969 plus TABS Elements May 1986 Exmouth 1967-1975, Learmonth 1975-1986, Yardie Creek 1957-1969. For Ningaloo (76 y), Vlaming Head (50 y), Yardie Creek (53 y) and Exmouth Gulf (56 y) based on Bureau of Meteorology (1977).

Landforms

The physiography of Cape Range has been described elsewhere (Condon *et al.* 1955; Condon 1968; Hocking *et al.* 1987). The range rises to an altitude of 311 m and forms the 16 km wide spine of the Cape Range Peninsula being fringed by coastal plains on its eastern and western margins (Figure 1). The crest of the range is gently undulating and there is both external drainage down the deeply dissected flanks of the range and centripetal drainage towards large sinkholes. The outcropping strata of Cape Range are Miocene and Quaternary limestones and possibly Pliocene calcareous sandstones (G.W. Kendrick, pers. comm. 1987), the oldest of which (Early Miocene) is the Mandu Calcarenite, a chalky, pliable formation about 240 m thick. Overlying conformably is 120 m of hard crystalline Tulki Limestone of Middle Miocene age (Condon 1968; Playford *et al.* 1975b). Across large areas of the central portion of Cape Range, the overlying strata (Trealla Limestone and Quaternary deposits) have eroded away leaving a rough surface of Tulki Limestone slabs, boulders and solution holes with shallow pockets of calcareous loams.

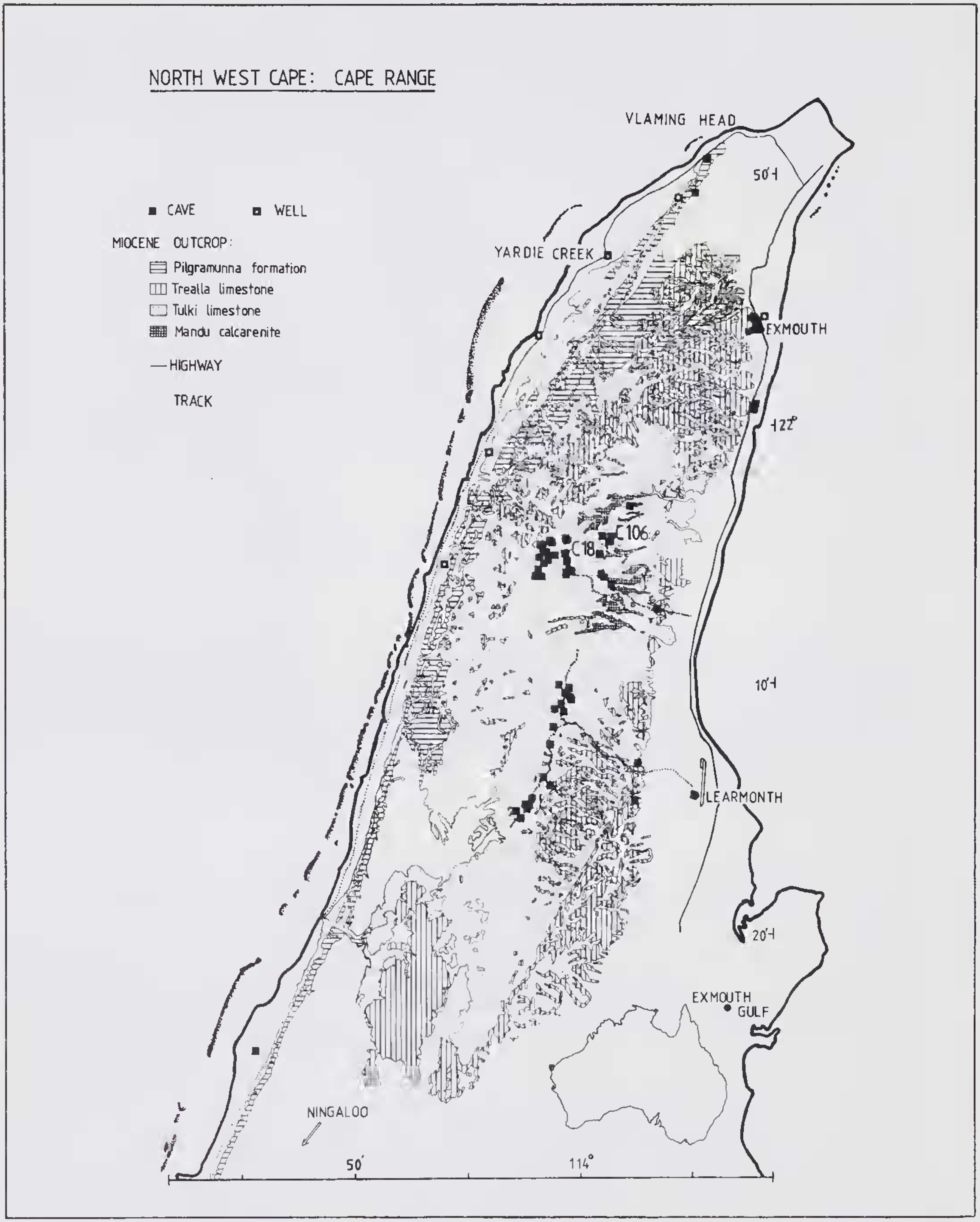

Figure 1 Map of North West Cape, Western Australia, showing the surface geology of Cape Range and the location of caves, including those inhabited by *S. vinei*.

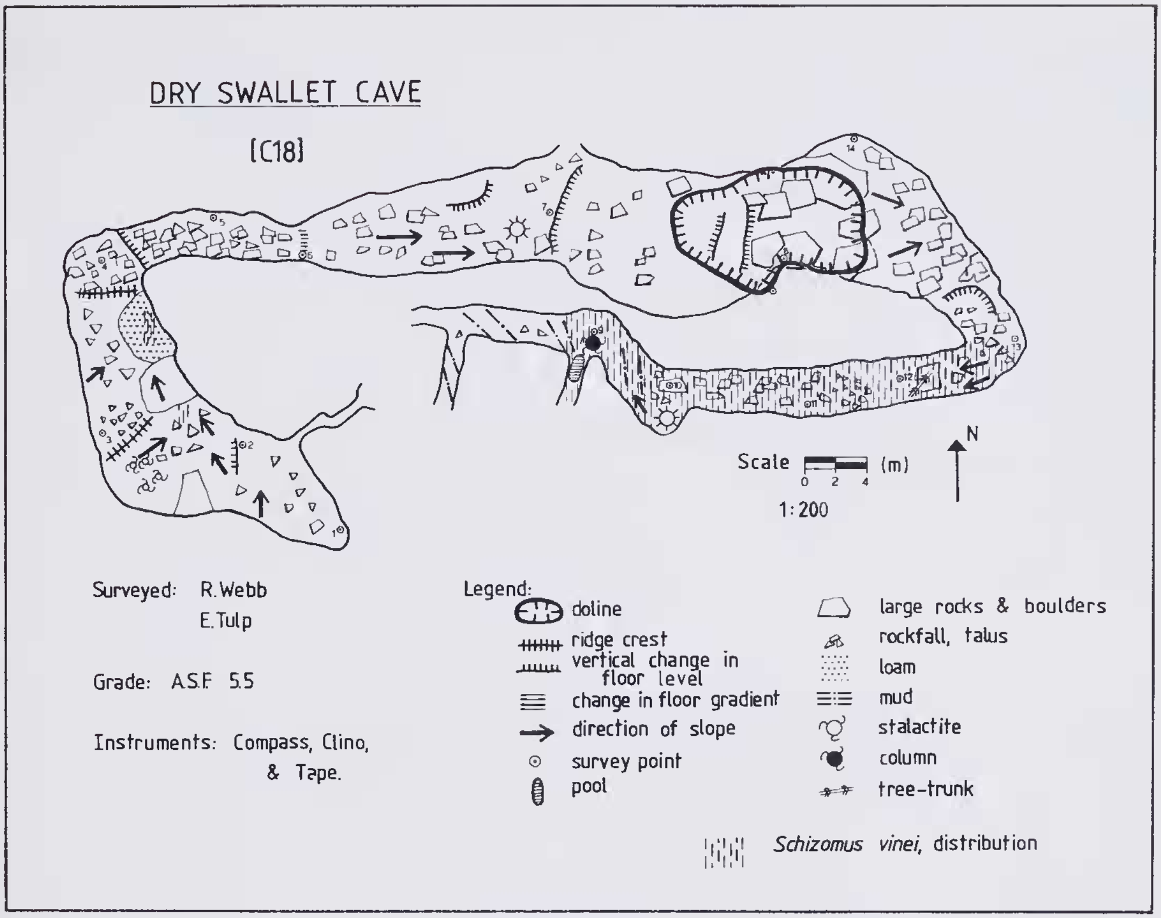

Figure 2 Plan view of cave C 18 (Dry Swallet) showing the main features of the cave and the sections inhabited by *S. vinei;* they were found usually in the lower right sector but were found in parts of the left hand arm only after flooding.

Caves

The supposition of Condon *et al.* (1955) that the cetripetal drainage towards sinkholes indicated well developed cave systems in the Tulki Limestone was later confirmed (Cook 1962). About 120 caves are now known from Cape Range and they have been assigned numbers by the Australian Speleological Federation (Matthews 1985). The genesis of these caves has not been studied but karst styles have been described from Barrow Island (Lowry, D.C. 1980), also lying within the Carnarvon Basin. The majority of caves in Cape Range are developed vertically with two only, C 64 (Shot Hole Tunnel; the only cave known in the Mandu Calcarenite) and C 15 (Papillon) known to have significant lateral development. Only 20% of the caves are deeper than C 106 (30 m; data from Matthews 1985). Although Cook (1962) believed that caves extending to sea level (300 m deep) could occur on Cape Range, with solution pipes in the hard Tulki Limestone connecting to caverns in the friable Mandu Calcarenite, none has yet been found. The deepest known cave is C 18 (*ca.* 50 m), now called Dry Swallet (Webb 1980) but also referred to as C 18 unnamed (Kendrick and Porter 1973, Shoosmith 1977), WAM 1 (Kendrick 1968) and Cave F (Janicke 1973); Gaping Gill (Cawthorn 1963) probably is also C 18.

Dry Swallet Cave, C 18 (22°05′S, 114°00′E): several gullies lead to a 7 m diameter undercut collapse vertical entrance leading into a 38 m deep chamber widened through roof and wall collapse; the floor being a talus-strewn watercourse. From the bottom of this illuminated (twilight zone) entrance chamber, tunnels lead beyond the twilight zone, one upwards in a westerly direction and another downward towards the east to an estimated total depth of 50 m (Figure 2).

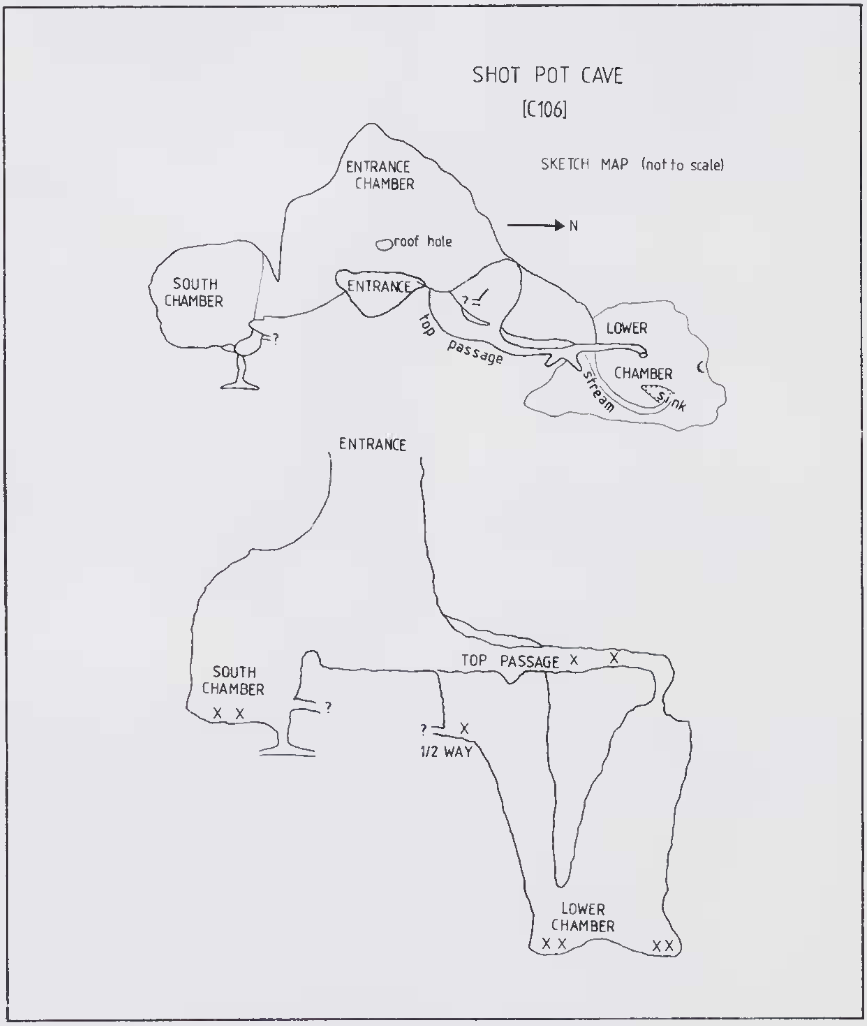

Figure 3 Plan and profile views of cave C 106 (Shot Pot) showing (X) the sections inhabited by *S. vinei*.

Shot Pot Cave, C 106 (22°05′S, 114°03′E): discovered by B. Vine in 1983. The vertical illuminated (twilight zone) entrance chamber (with a pitch of 19 m) leads from the bottom into two steeply descending side tunnels; one, with a depth of 5 m, is to the south and the second, a 25 m pitch to the north, is interrupted midway down by a ledge (Figure 3).

Occurrence

S. vinei has been found only in the non-illuminated lower extensions of C 18 and C 106, although *ca.* 60 of *ca.* 120 known caves in Cape Range have been surveyed for schizomids. Numerous caves probably await discovery as the area is rugged and most of the known caves are close to the two roads giving access to Cape Range; only *ca.* 12% of the Miocene strata outcropping in Cape Range has been surveyed for caves. Simple multiplication would suggest that schizomids may be found in between 16 and 32 caves in Cape Range. However the uncertainty of this estimate can be gauged by the need to examine 183 caves to have an 80% chance of detecting a 'true' difference between 3.3% (2/60) and 0% at a 5% level of significance (algorithms from Sokal and Rohlf 1981).

Associated fauna

There was an abundance of other invertebrates associated with the schizomids in both caves. In C 18 were oniscoid isopods (numerous), millipedes (numerous), scutigerimorph centipedes, spiders, beetles, cockroaches and Thysanura, and amphipods in the pool. There is no pool in C 106 but J.W.J. Lowry (1984) recorded an abundant and diverse invertebrate fauna, with earthworms, millipedes, isopods, small spiders, flies and mites being abundant, and larger spiders, beetles, psocids and Thysanura being uncommon; she collected 18 schizomids on this occasion.

Population size

At irregular intervals between 22 February 1984 and 1 June 1985 an assessment was made of the populations of schizomids, principally in C 106 (Table 3). On each visit counts of moving schizomids were made by the observer traversing the cave chambers along a set route; owing to the slow movement of schizomids it is unlikely that the same individual was recorded more than once per sampling session. Where possible, individuals were catergorised as adult, by virtue of their larger size and the rich chestnut colouration of their chelicerae and anterior head region, or juvenile (smaller and paler). No attempt has been made to convert these estimates to densities but in themselves these counts give an indication of the potential of the Cape Range populations for biological studies of schizomids as the catch per unit effort (0 to 5.8 individuals per hour) is substantially more rewarding than those recorded by Remy (1961; Table 3). The numbers seen in the four surveyed sectors of C 106 on eight days from 12 August 1984 through 1 June 1985 (Table 2) were correlated only between the upper and lower sectors of the northern extension ($r = 0.88$; $P < 0.05$). The mean number of *S. vinei* observed differed between chambers ($P<0.001$) being lower in the S. extension and mid-N. extension (1.3 and 1.9 per traverse respectively) and highest in the upper and lower northern extension (3.0 and 9.9 per traverse respectively); while there are no estimates of density, this indicates that the traverse technique achieves consistent results.

Table 2 Wet and dry bulb temperatures (°C) of cave C 106, the numbers of *S. vinei* (No.) and the time spent in the cave in 1984-5. The schizomids are thought to be juvenile unless specified as adult. In cave C 18 *S. vinei* were seen in numbers 6, 0, 3 (1 adult) and 10 on 15:5:84, 12:6:84, 25:8:84 and 13:9:84 respectively.

	South extension			North extension									Hours in cave	No. per hour
				Upper			Middle			Bottom				
Date	Wet	Dry	No.	Wet	Dry	No.	Wet	Dry	No.	Wet	Dry	No.		
12:8:84	17.0	18.0	0	-	-	-	-	-	-	-	-	-	3	0
5:9:84	17.5	18.0	0	18.5	19.0	2	18.0	18.5	1	18.0	18.0	2	3.5	1.4
22:9:84	18.5	19.5	0	19.0	19.5	2	18.5	19.0	1	18.0	18.5	6	4	2.3
10:10:84	19.0	19.5	1	19.5	20.0	4	19.0	20.0	0	19.0	19.3	9	4.5	3.1
21:10:84	19.5	20.0	1	20.0	20.5	7	19.3	19.7	1	19.3	19.5	49	10	5.8
17:12:84	20.0	20.5	0	20.0	20.5	2	20.0	20.5	2	20.0	20.5	14[1]	7	2.6
31:1:85	21.5	22.0	1	21.5	22.0	1	-	-	-	-	-	-	0.5	4
1:6:85	18.5	19.0	0	19.5	20.0	0	-	-	-	19.5	20.0	5	12.5	0.4

[1] 2 adults.

Cave environment

Both C 18 and C 106 have temperatures of about 20°C (Table 2), low levels of CO_2 and wet decaying organic debris (branches and leaf litter) on the cave floor. The schizomids occur in the dark zone associated with moist substrates (wet enough to soak through the seats of trousers). Where schizomids occurred, the wet bulb depression (measured using a whirling hygrometer) was never greater than 1°K (R.H.>91%; Table 2) Other caves in the area lacking schizomids are drier (by the 'seat of the trousers' test) and many have high levels of $C0_2$ (determined by the physiological response on cavers). Over one year the mean temperature between the four sections of C 106 (Table 2) did not differ significantly (mean 19.7°C; $F_{s3.22} = 0.92$, $P=0.447$) but the wet bulb depression (WBD °K) differed between chambers (mean 0.54°K; $F_{s3.22} = 3.62$, $P=0.029$) with the humidity being lower in the south extension (mean WBD 0.69°K) and high in the bottom of the northern extension (mean WBD 0.33°K). The number (N) of *S. vinei* observed during this time was associated with the humidity of the chambers ($\log N+1=1.01-1.04$ WBD; $F_{s1.24} = 11.41$, $P = 0.002$), even when one large outlier (Table 2; 21:10:84, bottom extension) is removed from the data ($P = 0.009$), despite the wet bulb depression ranging from only 0-1 °K.

Flooding

On 19-20 May 1984 230.8 mm of rain was recorded at Learmonth. A visit to C 106 on 22 May 1984 revealed that the cave had flooded to a depth of 27 m (i.e. into the base of the entrance chamber) and had already drained. No schizomids, dead or alive, were seen, although millipedes and isopods, both dead and alive, were seen and earthworms seemed unaffected by the flood. Following this episode an adult specimen was seen on 12 June 1984 but significant numbers were not seen again until 5 September 1984 when nine juveniles were seen in widely separate parts of the cave (Figure 2). By 22 September 1984 the schizomids appeared again to be well established throughout the cave except the entrance chamber, which by this time had dried out. As the upper reaches of the cave dried, so the schizomids retreated and by mid-1985 they were found only in the deeper, humid zones of the cave. A similar pattern of flooding and population recovery was observed in C 18. The schizomids may survive in air pockets within the cave or as eggs but the latency in the recovery of the population remains to be explained.

Behaviour

Little is known of schizomid behaviour (Kaestner 1968; Sturm 1973; Brach 1976). Most *S. vinei* seen were walking forwards at fairly constant speed with apparent aimlessness, but presumably hunting. While walking they repeatedly tested the ground ahead of them with their first (tactile) pair of legs. They occasionally stopped to groom a leg, seldom more than one at a time, by drawing it through their chelicerae; the first pair of legs being groomed most often. One individual, which had part of one first leg missing, groomed the first pair of legs almost exclusively, the injured one about twice as often as the contralateral leg. Schizomids were sometimes seen in groups of up to five individuals within a few cm of each other; Brach (1976) similarly found groups of *S. floridanus* beneath logs. Encounters between them were seen twice and on both occasions the schizomids jumped backward and turned to the left before they resumed walking. Three encounters with millipedes resulted in behaviour not noticeably different from conspecific encounters; the millipedes also turned away sharply. A sudden exposure to direct sunlight seems not to affect the schizomid's behaviour but they respond to air movement by remaining motionless for several seconds before they resume walking; repeated air movement causes them to run until shelter is reached beneath a leaf or into a hole. If provoked by the tip of a thermometer they appear unaware of its presence until actually touched. We have observed no defensive behaviour other than avoidance, in contrast to whip scorpions which spray substances over potential attackers (Kaestner 1968).

Laboratory observations

S. vinei from C 106 were maintained for two years from February 1984 at Exmouth in a terrarium containing mud and leaf litter from the cave. The whole was covered in black polythene sheeting to exclude light and distilled water added weekly to maintain humidity. The terrarium was stocked with millipedes, earthworms, isopods and beetles from the cave and a week later four schizomids added. Within two days only two schizomids remained; on four subsequent occasions one or two new schizomids were added but their numbers were always reduced to two within two days. The longevity of individuals within the terrarium is not known. On one occasion two *S. vinei,* of several in a polythene bag, grappled with each other and when they separated one was dead. Predation was never observed although beetle and isopod numbers slowly diminished and were replenished; millipedes and earthworm numbers remained unchanged. [We have since observed *S. vinei* eating an isopod in a cave and, in the laboratory, eating isopods, *S. vinei,* millipedes, cockroaches and earthworms]. Air temperature varied between 18-34°C without apparent ill effect on the schizomids but one kept in a terrarium in Perth vanished on the first day when temperatures exceeded 40°C. At Exmouth schizomids inadvertently exposed to low humidity died within six hours.

Discussion

Arthropods dominate cavernicoles and amongst the 11 extant orders of arachnids recognised by Levi (1982), subterranean forms are included in all but the desert adapted wind scorpions (Solifuga). Spiders (Araneae), mites (Acari), Pseudoscorpions and harvestmen (Opiliones) have been found in many Australian caves (Hamilton-Smith 1967, 1972; Lowry, J.W.J. 1980) and schizomids are known from caves in the other zoogeographic regions where they occur (Rowland 1975).

S. vinei is probably not a true troglobite (obligate cavernicoles with morphological adaptation to their subterranean life style). Restriction to the deeper, unlit areas of the caves most likely reflects their requirement for humidity and of food washed into the bottom of vertical caverns; only two caves have significant lateral extension of which one (C 37) is too dry while the other (C 64) has permanent water but has a substrate of washed sand or fine red silt lacking plant debris. Cavernicolous schizomids, including *S. vinei* are morphologically similar to their epigean counterparts: most are eyeless (but see Sissom 1980), with smooth areas on the propeltidium possibly representing vestigial eyes, and with long antenniform first walking legs. Schizomida, together with the Palpigradi, Pseudoscorpions, Ricinulei and Amblypygi, are all cryptozoic forms leading a semisubterranean life even when not cave dwelling. Consequently exploitation of the cave environment involves no major shift in biological strategies. We prefer to classify *S. vinei* as a second level troglophile (*sensu* Hamilton-Smith 1972), a form confined to caves but lacking the clear morphological adaptations of troglobites. Schizomid dependence on humidity has been emphasised repeatedly in the literature (McDonald and Hogue 1957, Rowland 1975, Savory 1977).

The occurrence of *S. vinei* in C 18 and C 106 raises questions about their origins and the possibility of their long term survival. The Exmouth Sub-Basin, including Cape Range, was covered by marine transgressions throughout the Cretaceous and Tertiary until the Miocene (Playford, Cope and Cockburn 1975). The nearest land from which the schizomids could have migrated was the north-eastern sub-basin of the Carnarvon Basin, and adjacent areas of the Western Precambrian Shield further to the east. Although modern schizomids have been transported by man well beyond their normal distribution to European botanic gardens (Savory 1977) and museums (Sturm 1973: 115), they most likely invaded Cape Range at a time when they were widespread across northern Australia under more favourable, humid conditions.

A latersol has developed over part of the Tertiary sequences in central Cape Range. This implies a weathering regime quite different from that prevailing in the area today – one requiring a significantly higher mean annual precipitation. The age of this paleosol has so far not been determined, and it may well be Late Tertiary or even Early Pleistocene in age (K.-H. Wyrwoll; personal communication 1987). While there is no reliable dating of the start of the present arid conditions in the Pilbara-North West Cape area, the present aridity of the Great Sandy Desert, quite inhospitable for schizomids, was established by 7000 BP (Wyrwoll *et al.* 1986).

The possibility that schizomids may raft should not be neglected, as they have colonised islands in the Indian (Table 3) and Pacific Oceans, including the Mascarene Is (Remy 1961), Samoa (Savory 1977), Galapagos (Reddell and Cockendolpher 1986) and Hawaii (Cockendolpher and Reddell 1986) which were never connected to continental land masses (Schmincke 1981). It is possible that they were introduced to some of these islands (Cockendolpher and Reddell 1986), as they have been to Europe, by man. Until the systematic position of *S. vinei* is known, together with the undescribed Australian species (Harvey 1988), the route by which it arrived at Cape Range must remain speculative. It should, however, not be forgotten that schizomids are a very ancient group and that their present distribution is consistent with a Gondwanic, even a Pangean origin.

Table 3 Schizomids caught per unit effort by Remy (1961) at various locations.

Location	No. caught	Hours spent searching	Captures per hour
India: Pondichéry	5	22	0.237
Ceylon: Zone littorale	13	40	0.325
Zone de Collines	15	53	0.283
Ile Maurice	3	80	0.038
Ile de la Réunion	5	150	0.033

The water catchments of C 18 and C 106 are of uncertain size but cover at least the area of the centripetal drainage into the caves. It is not known if the cave systems are connected or whether there is any underground drainage. Much of Cape Range is a National Park which includes both C 106 and C 18, but the area has been the focus for oil exploration and hydrocarbon impregnated roadfill has been used adjacent to the range. A single episode of pollution anywhere within a cave's water catchment could harm or eliminate a population. Surface changes which alter the deposition of debris and silt, or the humidity of a cave, could equally have deleterious effects on the schizomids and the associated cave fauna; this includes a pool dwelling amphipod in C 18 whose closest affinities lie with species from south-eastern Australia (Knott 1985).

Acknowledgements

We thank Mark Harvey for his prompt description of *S. vinei*. He, George Kendrick, Barbara Main, Bert Main and an anonymous referee made valuable criticisms of early drafts; the latter two people kindly assisted us with the literature. We thank Mike Newton for his continued cooperation.

References

Beard, J.S. (1975). *Pilbara: vegetation survey of Western Australia 1: 1,000,000 vegetation series. Explanatory notes to sheet 5; the vegetation of the Pilbara area.* University of Western Australia Press, Perth.

Brach, V. (1976). Development of the whip scorpion *Schizomus floridanus*, with notes on behaviour and laboratory culture. *Bull. Southern California Acad. Sci.*, 74: 97-100.

Burbidge, N.T. (1960). The phytogeography of the Australian Region. *Aust. J. Bot.* 8: 75-211.

Bureau of Meteorology (1977). *Rainfall statistics, Australia 1977.* Metric edition. Department of Science, Bureau of Meteorology, Canberra.

Cawthorn, P. (1963). Discovery of subterranean freshwater fauna on the eastern side of North West Cape. *West. Aust. Naturalist* 8: 129-132.

Cockendolpher, J.C. (1981). The Order Schizomida. *Australian Arachnology* 5 April 1981.

Cockendolpher, J.C. and Reddell, J.R. (1986). *Schizomus siamensis* (Schizomida: Schizomidae) from eastern Asia and Hawaii. *Acta Arachnol.* 35: 23-28.

Condon, M.A. (1968). The geology of the Carnarvon Basin, Western Australia. Part III: Post-Permian stratigraphy; structure; economic geology. *Aust. Bur. Mineral Resources Bull.* 77, pp. 1-68.

Condon, M.A., Johnstone, D. and Perry, W.J. (1955). The Cape Range structure, Western Australia, Part 1. Stratigraphy and structure. *Aust. Bur. Mineral Resources, Geology and Geophysics.* Bull. No. 21 (2nd edition). Department of National Development, Canberra. pp. 7-48 + maps.

Cook, D. (1962). Caves of the Cape Range, North West Cape, Western Australia. *J. West Aust. Speleological Group of the West. Aust. Naturalists Club 1962*, pp 4-11.

Gentilli, J. (1971). The main climatological elements. In: J. Gentilli (Ed.), *World survey of climatology vol. 13, Climates of Australia and New Zealand.* Elsevier, Amsterdam, pp. 119-188.

Gentilli, J. (1972). *Australian climatic patterns.* Nelson, Melbourne.

Gentilli, J. (1979). Epitropical westerly jet advected storms. *Qld Geog. J.* (3rd Ser) 5: 1-20.

Hamilton-Smith, E. (1967). The Arthropoda of Australian Caves. *J. Aust. ent. Soc.* 6: 103-118.

Hamilton-Smith, E. (1972). Some aspects of the Australian cavernicolous fauna. In: *Proceedings of the 8th Bienniel Conference of the Australian Speleological Federation: December 1970.*, pp. 93-100.

Harvey, M.S. (1988). A new troglobitic schizomid from North West Cape, Western Australia (Chelicerata: Schizomida). *Rec. West. Aust. Mus.* 14 (1):

Hocking, R.M., Moors, H.T., and van de Graaff, W.J.E. (1987). Geology of the Carnarvon Basin Western Australia. *Geol. Surv. West. Aust. Bull.* 133: 1-289.

Janicke, S. (1973). Trip report on caves on North West Cape. *Western Caver* 13: 88-93.

Kaestner, A. (1968). *Invertebrate zoology vol II. Arthropod relatives, Chelicerata, Myriapoda.* Trans. H.W. Levi and L.R. Levi. Wiley Interscience, New York.

Kendrick, G. (1968). 1965 Western Australian Museum Cape Range Trip. *Western Caver* 3: 64-67.

Kendrick, G.W. and Porter, J.K. (1973). Remains of a thylacine (Marsupialia: Dasyuridae) and other fauna from caves in the Cape Range, Western Australia. *J. Roy. Soc. West. Aust.* 56: 116-122.

Knott, B. (1985). Australian aquatic cavernicolous amphipods. *Helictite* 23: 51-55.

Lawrence, R.F. (1969). The Uropygi (Arachnida: Schizomida) of the Ethiopian region. *J. Nat. Hist.* 3: 217-262.

Levi, H.W. (1982). Schizomida. In: *Synopsis and classification of living organisms.* Vol. 2, McGraw-Hill, New York, pp. 122.

Lourensz, R.S. (1981). *Tropical cyclones in the Australian region, July 1909 to June 1980.* Department of Science and Technology, Bureau of Meteorology, Canberra.

Lowry, D.C. (1980). Karst styles in Western Australia. *WACCON: Proceedings of the 12th Bienniel Conference of the Australian Speleological Federation. Perth 1979.*

Lowry, J.W.J. (1980). Ecological relationships of Western Australian cavernicoles. Unpubl. M.Sc. thesis, University of New South Wales, Sydney.

Lowry, J.W.J. (1984). Cape Range. *Western Caver* 24: 23-25.

McDonald, W.A. and Hogue, C.L. (1957). A new *Trithyreus* from southern California (Pedipalpida, Schizomidae). *Am. Mus. Novitates* 1834: 1-7.

Main, B.Y. (1980). Record of the arachnid order Schizomida in Western Australia. *West. Aust. Nat.* 14: 236-237.

Matthews, P.G. (1985). *Australian karst index 1985.* Australian Speleological Federation Inc., Broadway, New South Wales.

Petrunkevitch, A. (1955). Order Schizomida. In: Treatise on invertebrate palaeontology. R.C. Moore (Ed.), *Arachnida. Part P. Arthropoda 2. Arachnida.* American Palaeontological Society, University of Kansas, Texas, pp. 122-124.

Playford, P.E., Cope, R.N. and Cockburn, A.E. (1975). Palaeogeographic development of Western Australia: Phanerozoic. *The geology of Western Australia, West. Aust. Geol. Survey, Mem. 2*, 451-460.

Playford, P.E., Cope, R.N., Cockburn, A.E., Low, G.H. and Lowry, D.C. (1975b). Phanerozoic: Carnarvon Basin. *The geology of Western Australia, West. Aust. Geol. Survey, Mem. 2*, 269-318.

Reddell, J.R. and Cockendolpher, J.C. (1986). New species and records of *Schizomus* (Arachnida: Schizomida) from Mexico. *Texas Mem. Mus. Speleol. Monogr.* 1: 31-38.

Remy, P.A. (1961). Sur l'écologie des schizomides (Arachn. Uropyges) de mes récoltes, avec description de trois *Schizomus* noveaux, capturés par J. van der Drift au Surinam. *Bull. Mus. Hist. Nat., Paris. ser. 2*, 33: 406-414.

Rowland, J.M. (1975). Classification, phylogeny and zoogeography of the american arachnids of the Order Schizomida. Ph.D. thesis, Texas Tech University, Texas.

Rowland, J.M. and Reddell, J.R. (1981). The order Schizomida (Arachnida) in the New World. IV. *Goodnightorum* and *Briggsi* groups and unplaced species (Schizomidae: *Schizomus*). *J. Arachnol.* 6: 161-196.

Savory, T.H. (1977). *Arachnida.* 2nd Edn. Academic Press, London.

Schmincke, H-K. (1981). Volcanic activity away from plate margins. In: D.G. Smith (Ed.) *Cambridge encyclopaedia of earth sciences.* Cambridge University Press, Cambridge, pp. 201-209.

Shoosmith, R. (1977). Western Australian cave nomenclature; list # 14. *Western Caver* 16: 71-74.

Sissom, W.D. (1980). The eyed schizomids, with a description of a new species from Sumatra (Schizomida: Schizomidae). *J. Arachnol.* 8: 187-192.

Sokal, R.R. and Rohlf, F.J. (1981). *Biometry: the principles and practice of statistics in biological research.* W.H. Freeman and Company, San Francisco.

Sturm, H.·(1973). Zur Ethologie con *Trithyreus sturmi* Kraus (Arachnida, Pedipalpi, Schizopeltidia). *Z. Tierpsychol* 33: 113-140.

Webb, R. (1980). The 1980 Cape Range Expedition. *The Western Caver* 20: 79-85.

Wyrwoll, K.-H., McKenzie, N.L., Pederson, B.J. and Tapley, I.J. (1986). The Great Sandy Desert of northwestern Australia: the last 7000 years. *Search* 17: 208-210.

Received 9 June 1987 Accepted 30 October 1987 Published 10 June 1988